FRD Activities Report
September 2003

Research Programs

CBLAST-High

CBLAST Hurricane researchers were blessed with two major tropical systems during September. Both systems formed in the mid-Atlantic and tracked westward passing just north of the U.S. Virgin Islands. Both of these storms were situated such that multiple missions could be flown over a span of three days to allow for investigation of the storm evolution.

Figure 1. NOAA P-3 (N43RF) with BAT probe deployed in St. Croix for research flights into Hurricane Fabian.

On September 1, both NOAA P-3's were deployed to St. Croix for staging research flights through Hurricane Fabian. At that time Fabian was a category 3 hurricane and forecast to at least maintain intensity as it continued a general west-northwest track. Both P-3's flew three missions on consecutive days, during which time Fabian increased in intensity to a category 4 hurricane. N43RF (Figure 1) completed stepped descent patterns (see August 2003 Monthly Report) between rain-bands on all three days in an attempt to retrieve measurements necessary to estimate surface fluxes. Data from the BAT probe instrument suite was the focus of the measurements for these flights.

During the three flights in Fabian, the BAT probe performance was only good to marginal with the quality of the data collected deteriorating through the deployment. It was later discovered that water was seeping into the probe hemisphere and getting on the electronics, causing unpredictable behavior of the probe's sensors. For the initial flight in Fabian (September 2), N43RF completed one entire stepped descent pattern in roughly 40-45 kt surface winds. During this pattern, the BAT probe operated perfectly and should provide good flux data. During the second and third flights into Fabian (September 3 and 4) the intrusion of water into the BAT hemisphere began creating problems. On September 3 a series of stepped descents were made in 70-75 kt surface winds. The pressure sensor that determines sideslip was not operating properly during this sequence of legs. We still may be able to determine sensible and latent heat flux, but momentum flux will not be able to be retrieved from this sequence. Between the second and third flights, the BAT probe was disassembled and the water intrusion into the sphere was discovered. The sensor board was thoroughly cleaned and some attempt was made to prevent additional leakage for the subsequent flight. The third (and final) flight into Fabian resulted in more water intrusion and a likely unusable data set from the BAT probe.

Following the deployment for Fabian, the BAT sphere was removed from the P-3 and returned with Jeff French to FRD. There was a window of only two days in which to make changes to the design/manufacture of the sphere before the next deployment for Hurricane Isabel. Upon inspection it was determined that water was coming into the sphere through the center port. This is the largest port, designed to act similar to a pitot tube and be relatively insensitive to flow angle changes. Ventilation holes near the back of the port were allowing water to stream through and drip onto the electronics. To remedy this, the port (on the inside of the hemisphere) was encased in a sealed PVC tube roughly twice as large in diameter. A drain was placed in the bottom of the tube and carried through to a drain hole that was located on the mounting cone directly behind the hemisphere. The electronics board was thoroughly cleaned and bench-tested in the laboratory before being mounted back inside the hemisphere and shipped to NOAA/AOC for reinstallation on the P-3. Two days after the completion of this work, the P-3s were again deployed, this time for flights through Hurricane Isabel.

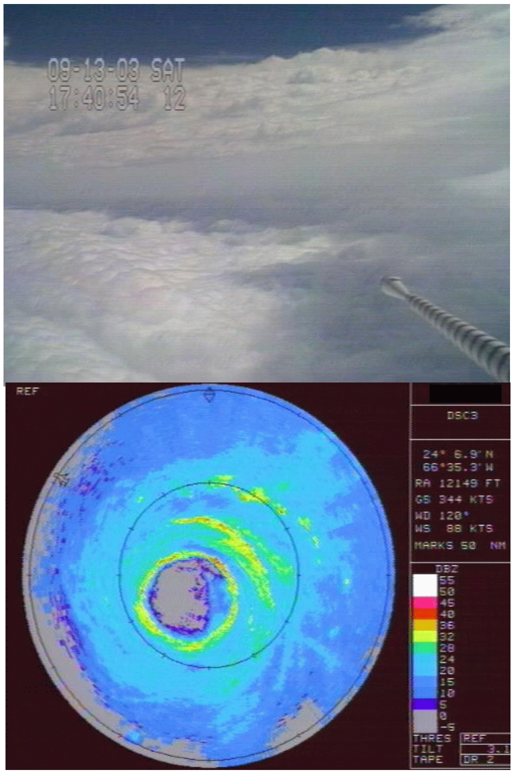

Figure 2. Forward view from the NOAA P-3 cockpit (top) as it circles in Hurricane Isabel's eye (note the BAT probe at end of nose boom). P-3 belly radar image (bottom) during the time the P-3 was on the NE side of the eye.

During the flights in Fabian, water seepage occurred primarily during the early portion of the pattern while penetrating the eyewall to map the storm structure. In Isabel we found that even following two to three eye penetrations, the probe electronics seemed to work fine. For the first two flights in Isabel (Figure 2), two full sets of stepped descents (along-wind and cross-wind) were made. The BAT probe operated flawlessly during these patterns. On the third flight (September 14), one full set of stepped descents was completed and an additional set of "modified" stepped descents including slightly longer legs in a different region of the storm were completed. Throughout this flight, the BAT once again operated flawlessly. It is anticipated that the dataset from Isabel

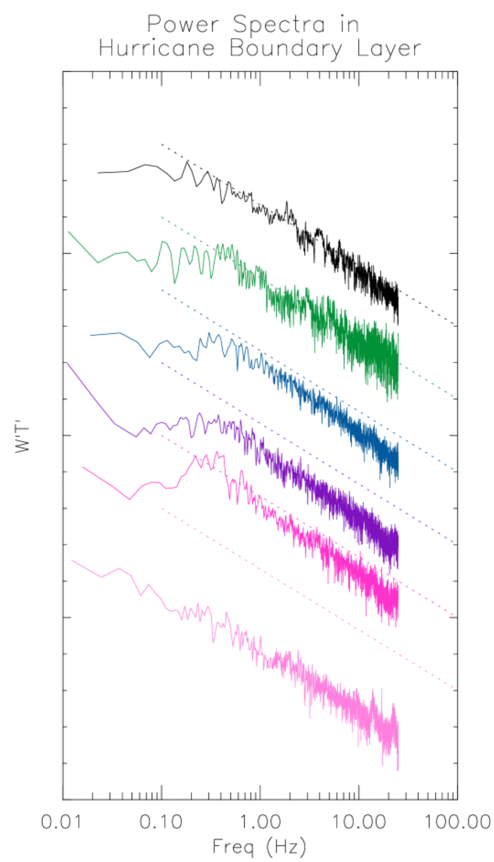

Figure 3. Power spectra of w'T' from 6 flight levels in Hurricane Fabian (see text for further explanation).

and the first flight in Fabian should provide several unique series from which to begin the examination of the fluxes in a high wind boundary layer.

Currently, data from both hurricane deployments are being processed as the project focus shifts from data collection to analysis. Figure 3 shows a series of simple spectra for w'T' for stepped descents from the first flight in Fabian. The spectra were taken from legs at 200 ft (black), 400 ft (green), 600 ft (blue), 900 ft (violet), 1200 ft (pink), and 2500 ft (lt. purple). The spectra are plotted as a function of frequency (time), and are not yet corrected for aircraft flight speed. The dashed lines represent a common scale and a –5/3 slope for each of the spectra. These lines range from 10^{-2} at f=0.1 Hz to 10^{-7} at f=100 Hz. Note that the relative power decreases with increasing height and is roughly 2 OM less at 2500 ft than near the surface. Figure 4 shows the standard deviation of the vertical velocity over entire legs as a function of altitude. In general, the standard deviation increases from a minimum above the top of the boundary layer to a maximum near the surface (~200 ft). The analysis has just begun, but we feel that these graphs demonstrate our ability to acquire usable measurements with the BAT probe in the hurricane boundary layer. (Jeff.French@noaa.gov, Shane Beard, Randy Johnson)

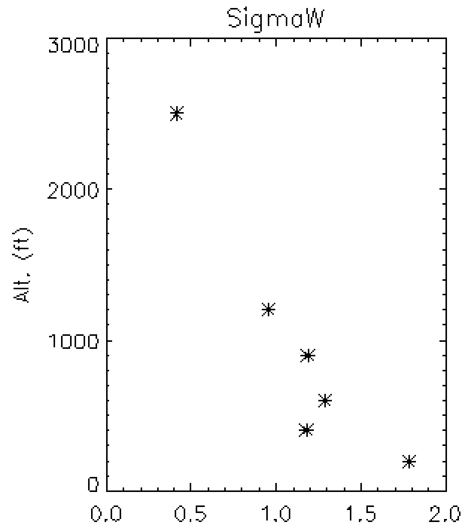

Figure 4. Standard deviation of w as a function of altitude for six stepped descents legs in Hurricane Fabian.

ET Sphere

An accelerated effort was made early in September to get the ET spheres ready for deployment in a hurricane. Three spheres had been shipped from ATDD in late August, and it quickly became apparent that considerable work would be required to get them in working order. One sphere did not have any temperature sensors, so it was decided to focus on the other two spheres. They were first tested and calibrated in the lab, and then taken out for some field tests using FRD's specially designed rig on a pickup truck (Figure 5). One sphere functioned without any problems, but the other one had an intermittent failure with one of the temperature sensors. Eventually, the wiring harness used for the temperature sensors was replaced. One of the spheres also had a bad

Figure 5. ET sphere testing rig on a FRD truck.

solder joint on one of the circuit boards.

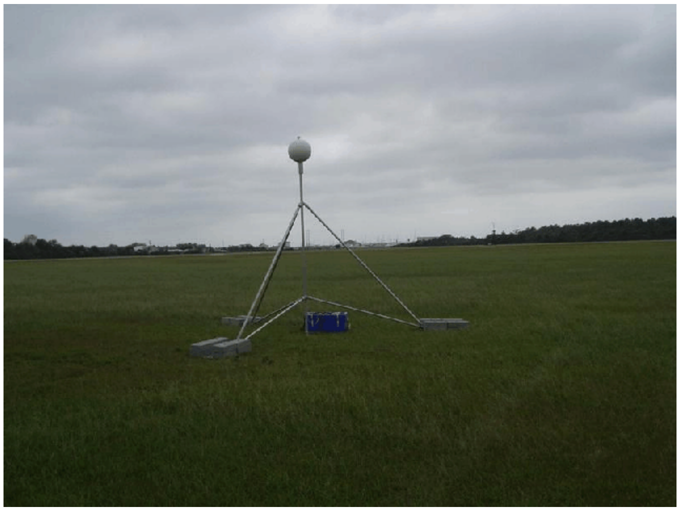

Figure 6. ET probe deployed at Beaufort, NC on 17 September 2003. Hurricane Isabel made landfall the next day just north of this site.

The spheres were completed just in time for deployment into Hurricane Isabel, which was predicted to reach the U.S. East Coast in mid September. The spheres were shipped back to ATDD so that they could be packed with the towers that were required for deployment. On 16 September, two FRD staff members departed for North Carolina to deploy the spheres in Isabel. They were met by Ron Dobosy from ATDD, and then proceeded to New Bern, NC, just inland from the point where Isabel was expected to make landfall. One of the spheres was deployed on 17 September at an airport near the coast in Beaufort, NC (Figure 6). Texas Tech University also deployed instrumentation at this site, which will be valuable for intercomparison with the ET sphere. The second sphere was to be deployed in New Bern, but it had been significantly damaged during shipment; the damage was repairable, but not in time for Isabel's landfall.

Isabel made landfall during the afternoon of the 18th (Figure 7), just north of the Beaufort ET sphere. The sphere either went through the eye or through the eyewall on the south side of the storm. When the crew returned to Beaufort on the 19th, the ET sphere was still operating normally. It ran uninterrupted for over 36 hours, generating about 1.2 Gbytes of data. Analysis of the data has not yet begun. It was apparent, however, that rain water had entered some of the pressure ports and affected the wind computations. The original plans for this fiscal year included the development of a back-flushing system for the ports, but this was deferred because project funding from the Office of Naval Research was not received until June 2003.

Figure 7. View from hotel window of Hurricane Isabel's storm surge. Most of the area between the trees in the foreground and the bridge behind them was grass a few hours earlier.

Overall, the deployment went remarkably smoothly. It provided ARL with valuable experience on the logistics of hurricane deployments. Moreover, both the tower design and the spheres themselves held up well to the punishment dealt out by Isabel. (Richard.Eckman@noaa.gov and Tom Strong, FRD; Ron Dobosy, ATDD)

CBLAST-Low

Work is ongoing with the analysis of fluxes and transfer coefficients and the comparison of aircraft results with the COARE bulk algorithm results. Two versions of the COARE algorithm have been used. When the latest version (v3) became available, the Fortran code was converted to IDL and applied to the data from the 2001 field campaign. This latest version includes two models that account for the sea state through either a wave age parameterization or wave slope parameterization. Work has been directed at determining the wave state parameters from the aircraft laser data. It was necessary to write code based on the algorithm presented by Sun *et al.* (2003). In this paper (currently under review) Sun *et al.* demonstrate the capability to determine the true wave number and the wave propagation speed and direction based on data from the laser array. Sun *et al.* present the theoretical basis and data from the SHOWEX project, thereby demonstrating the capability. Figure 8 shows an FFT from one of the lasers for data taken from two opposing flight directions on 25 July. The primary wave number is easily discerned from the peak in the spectra. The change in the location of the peak is due to the Doppler shift in the encountered frequency between two opposite headings. The wave propagation direction will be determined by comparing the phase at the peak frequency for all three lasers in the array.

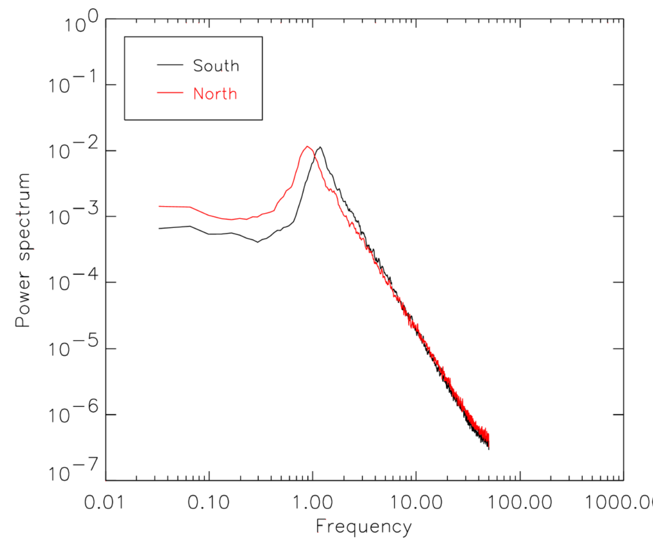

Figure 8. Power Spectra from the laser altimeter for two flight legs (north & south) illustrating encountered frequency and Doppler shift for dominant wavelength.

Figure 9 shows comparisons between neutral drag coefficient (C_{D-10N}), z_0, u* computed rigorously using LongEZ high-frequency (HF) data and the COARE algorithm (v3) with inputs taken from 60 second averaged LongEZ measurements. These data comprise all flights in the CBLAST 2001 field campaign. The results are averaged based on 0.5 ms^{-1} wind speed bins. For wind speeds up to roughly 8 ms^{-1}, there is generally good agreement between the COARE algorithm and the aircraft HF measurements/calculations. Above 8 ms^{-1}, the aircraft HF measurements are significantly less than the COARE. This regime is based on three days of data, one of which shows reasonable agreement. For the comparison between drag coefficient, there exists similar behavior for winds above 8 ms^{-1}. Also for moderate-light winds (4-6 ms^{-1}), the aircraft HF measurements are less than the COARE. For our present research we are investigating whether differences in sea state may account for these differences.

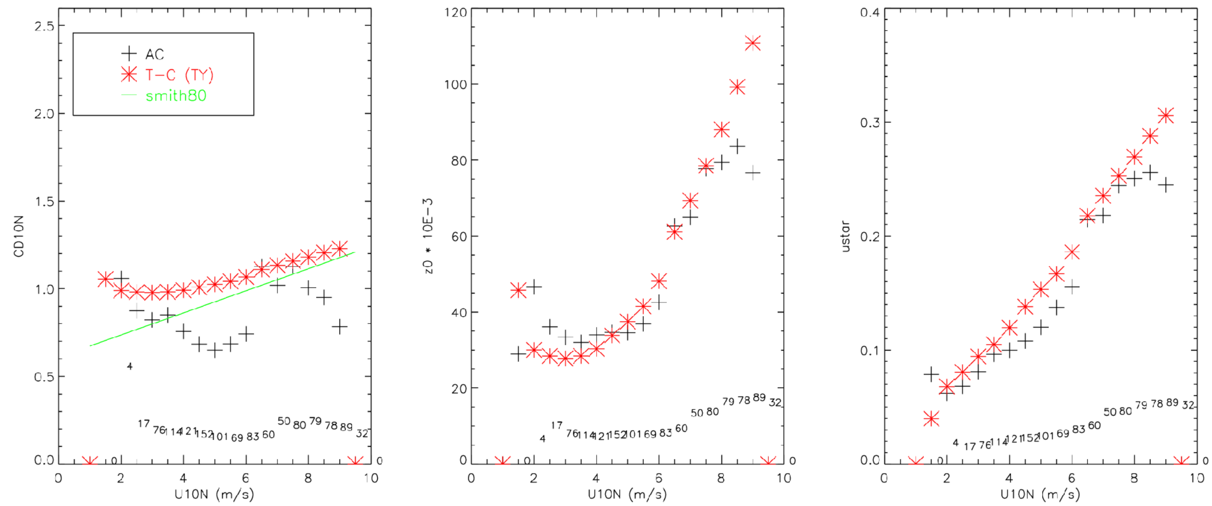

Figure 9. Drag Coefficient ($C_{D\text{-}10N}$), Z_0, and U* as a function of 10 meter-neutral wind speed for the Long-EZ high frequency data and calculated from the COARE algorithm (Long-EZ 60 second averages) for all days in the CBLAST 2001 field campaign. Data are averaged over 0.5 ms^{-1} bins, numbers at bottom represent number of data points in each bin.

Figure 10 shows comparisons for latent heat flux (H_l) and sensible heat flux (H_s) for all of the flights from the 2001 field campaign. In general, comparison is good between the aircraft calculated values and that computed using the COARE algorithm. The aircraft calculations are less than the COARE values for latent heat flux at low values (possibly a sensor issue with the IRGA) and are greater than the COARE for sensible heat flux at high values. The FUST sensor (utilizing a thermocouple and designed to respond much faster than the standard BAT fast response thermistor bead) was also flown in CBLAST. The FUST does not suffer from high frequency noise contamination due to vibration and stress of the element. Data from this sensor are being processed for use in further analyses. These data may shed light on the descrepency between the sensible heat flux calculations. (Jeff.French@ noaa.gov, Tami Grimmett)

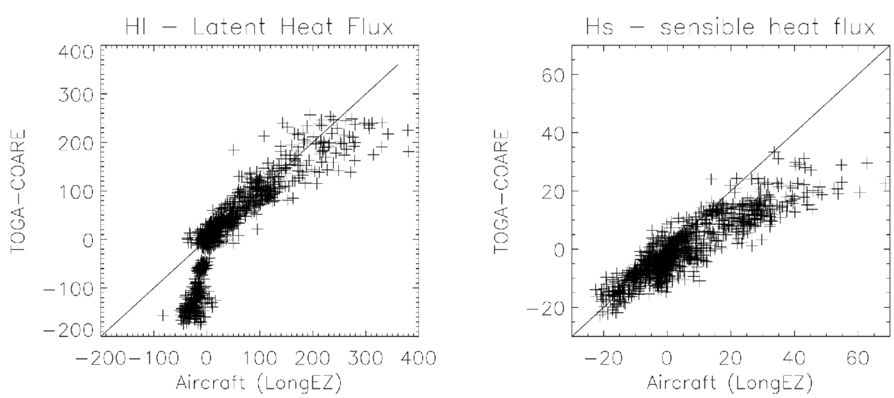

Figure 10. Latent Heat Flux and Sensible Heat Flux calculated from all flights in CBLAST Low for Long-EZ HF measurements and COARE algorithhm using 60 s averaged Long-EZ data for input.

JOINT URBAN-2003

Studies continued to be conducted on the new plastic samplers to try to pin down the reasons for the bad quality control (QC) data from the URBAN-2003 study done in July. Studies are also being done to compare the newer plastic samplers (Super PIGS) to the old cardboard samplers (PIGS). So far, some of the bad data from the plastic samplers can be directly traced to at least two samplers that did not function properly. Further studies on all samplers will eventually be done to verify that the remaining samplers worked properly. The two samplers known to have failed will be carefully disassembled to pinpoint the reasons for their failures. All other plastic samplers will be checked to verify that the problems discovered in the non-functioning samplers do not appear in any other samplers.

Tests have also been conducted to try to mimic the weather conditions found in Oklahoma City during the time of the study. A confined hot box was constructed that can house several samplers, a heater, a fan and a pan of water to increase humidity in the box, if needed. Tests have been conducted on the effects of heat and humidity on sampler performance. Sulfur hexafluoride has been injected into the box to compare the sampling mechanism between the plastic and cardboard samplers. Initial results show that there is minimal effect from heat or humidity and the different samplers compare favorably. Leakage from somewhere in the system seems to be the main reason for the discrepancies. (Debbie.Lacroix@noaa.gov, Roger Carter)

The data analysis for the continuous SF_6 analyzers has been continuing throughout the month. Each data set from the continuous analyzers must be examined carefully to ensure that calibrations meet the QC criteria, all SF_6 peaks have been identified, and no peaks caused by interfering chemicals or other sources are included. The identified peaks must then be extracted and instrument baseline subtracted out. We estimate that this effort is currently about 75% complete. (Roger.Carter@noaa.gov, Debbie Lacroix)

Smart Balloon Research

Research has begun into improving the battery performance lifetime of the balloon. Two approaches are being investigated: solar chargers and fuel cells.

Solar Charger - A lightweight solar battery charger (Figure 11) has been built and tested. The charger uses a 4.8 volt thin-film solar cell to charge 3.6 volt lithium-ion rechargeable batteries. These batteries are charged up to their maximum capacity of about 4.2 to 4.4 volts. The charger and pack of three batteries were allowed to charge over several days in typical weather and sunlight conditions and then were taken into the lab to test the actual capacity of the batteries working with two different load resistors. Results of the tests are shown in the accompanying three graphs.

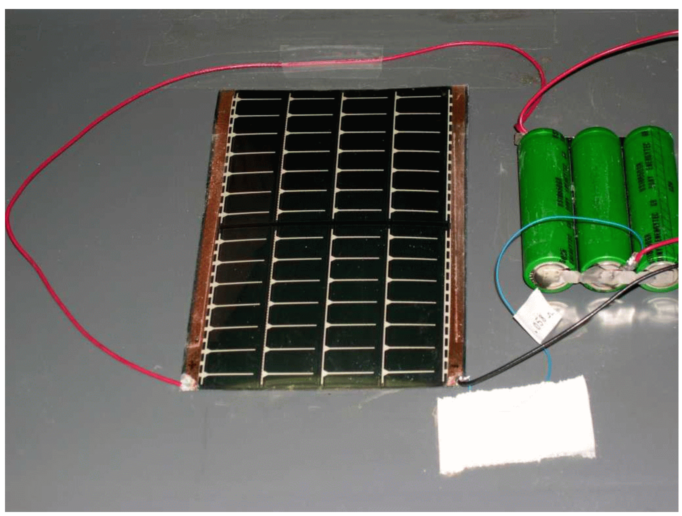

Figure 11. Solar charger and batteries.

The top graph of Figure 12 shows the charge characteristics of the batteries while connected to the solar cell over a four day period. The graph clearly shows the daytime step increases in battery voltage over the test period as indicated by the blue line. The first 3 peaks of the red trace indicate clear, cloudless days while the 4th and what is available of the 5th daytime cycle show partly cloudy skies as indicated by the noise in the charging current. The average charging current over the four days was 21 milliamps. It will be necessary to have about 20 times as much average current to maintain a charge on the batteries while the transponder is in operation. This will require a solar panel with an area of about 2.5 square feet. Efficiency might also be increased somewhat by using a switching power supply to provide better energy conversion efficiency throughout the day.

The middle graph of Figure 12 shows the discharge voltage curve and total energy delivery of the battery pack connected to a fast discharge, 1.5 ohm load. The bottom graph shows the same battery pack, after recharging, connected to a more reasonable 8.9 ohm load. It is interesting to note that overall energy delivered at the high discharge rate is about 13 watt-hours while at the slower rate of discharge rate the total energy delivered was about 21 watt-hours. One culprit in the much lower total energy of the high discharge rate can be seen by looking at the initial battery voltage when the discharge cycle begins. The initial voltage of the fast discharge test showed around 3.6 volts while the slower discharge test showed around 4.2 volts. The voltage difference of 0.6 volts is due to the internal resistance of the battery which dissipates this energy as heat inside the cell during the discharge cycle. However, an even larger problem is the lower conversion efficiency of the battery chemistry at the higher discharge rate. This is borne out by the fact that the fast discharge rate delivered a total of about 4 ampere-hours of current while the slower discharge rate delivered around 6 ampere-hours of current. In actual operation, 24 to 36 cells in parallel will be discharged at one third to one fourth the current per cell than the discharge

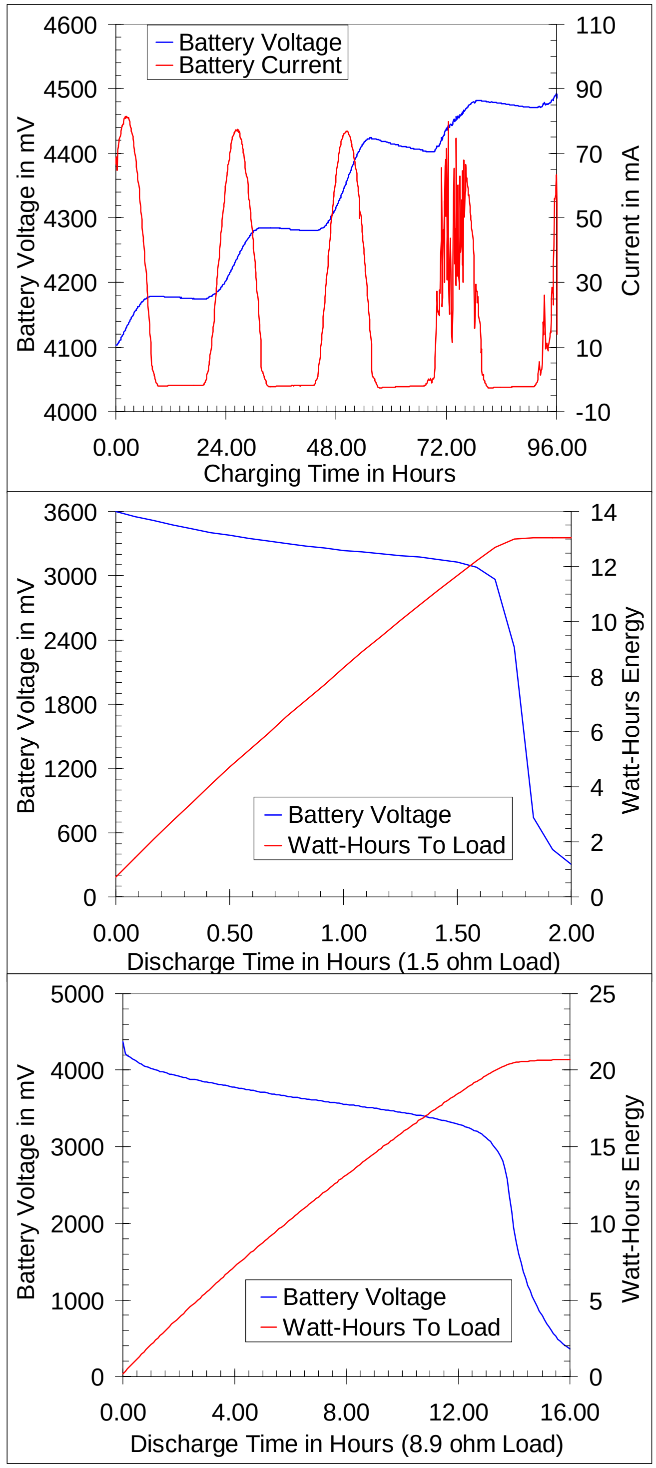

Figure 12. Charge curve for solar charger (top), fast discharge curve (middle) and slow discharge curve (bottom).

rate of the low current test. This will provide even greater energy per cell during actual operation in the smart balloon transponder.

Fuel Cells - One of the proposed means of providing energy for the smart balloon transponder is the use of a fuel cell. However, there have not been any small fuel cells available for small applications of the size of the smart balloon transponder. Although small fuel cells have been talked about for many years, there have not been any commercially available. In mid-September, NEC Corp. and Toshiba Corp. announced and demonstrated prototypes of fuel cells (Figure 13) that they claim will be used in their notebook computers before the end of next calendar year (2004). The direct-methanol fuel cells weigh about 900 grams each and can power a notebook computer for five hours with one 50 cc container of methanol fuel. NEC also intends to market a notebook equipped with an internal fuel cell that offers 40 hours of continuous operation by the end of 2005. Toshiba claims to have an average output of 12 watts for the fuel cell. Delivering 40 hours of operation at 12 watts would give a total output of 480 watt-hours from a single fuel cell with the large capacity (400 gram) methanol pack. Of major concern are the actual cost of these fuel cells and if they will be made available for other applications by either of these companies or some other manufacturer at a reasonable price for use on the smart balloon.

Figure 13. Prototype notebook computer with a fuel cell (above) and methanol fuel cartridge (right).

Fiberglass Enclosure - A prototype fiberglass enclosure has been designed and fabricated using fiberglass wound on a precision mandrel. The outside diameter is then precision ground to give a very smooth, precision outside diameter which is nearly glass smooth and suitable to seal the balloon bladder against. This allows the dimensions to be closely controlled, gives very high strength, no leakage and less than half the weight of the PVC enclosures used previously.

To test leakage and strength, a 320 millibar (4.6 psi) vacuum was pulled inside the prototype with circular 0.032 inch fiberglass plates sealed on both ends. The strength of the end caps and the cylinder were more than adequate and the loss of vacuum was minimal over a two day test. Weight savings will be gained by using a thinner (0.032 inch) silicone rubber elastomer rather than the two layers of 0.062 inch latex elastomers used previously. Additional weight savings will be gained by using a single wrap of 0.064 inch diameter 304 soft

Figure 14. Fiberglass transponder enclosure during test.

stainless steel wire to clamp the bladder to the transponder enclosure.
(Randy.Johnson@noaa.gov, Shane Beard)

BRACE

An oral and a poster special session covering the results of the Bay Region Atmospheric Chemistry Experiment (BRACE) Intensive Field Program will be held at the Fall American Geophysical Union Meeting to be held December 8-12 in San Francisco. The goal of BRACE was to improve our understanding of atmospheric nitrogen deposition to Tampa Bay. Tampa Bay is one of the most important Gulf Coast estuaries. There has been a reduction of 72% in the sea grass coverage in the bay over the last 70 years caused by anthropogenic nitrogen inputs. Twenty-nine per cent of this nitrogen input is estimated to come from direct atmospheric deposition. BRACE was executed during the month of May, 2002, and involved more than 50 researchers from 12 Federal and State agencies and universities. ARL scientists flew over 80 hours on the NOAA Twin Otter making chemical and meteorological measurements as well as ground-based flux and deposition measurements. These data will be used to test various deposition models. The BRACE AGU special session will allow researchers to present the results of the experiment and promote cooperation, collaboration, and interdisciplinary connections. The sessions will consist of 8 talks and 11 posters.

Analysis of BRACE data continues. Currently, Matlab computer programs are being used to extract the chemical and meteorological data for all vertical profiles flown during each flight and to compute flight track averages and running averages for each flight leg. The processed data will be compiled and distributed to the ARL investigators. (Tom.Watson@noaa.gov)

Cooperative Research with INEEL

Emergency Operations Center (EOC)

The INEEL Annual Exercise was conducted on September 24. Jeff French and Brad Reese represented FRD in the INEEL EOC. The scenario consisted of a simulated radioactive/toxic gas release from an underground storage tank at the INTEC facility. Special meteorological files (see article below) were used together with the transport and dispersion model MDIFF to determine the extent of the plume. The exercise is required to maintain the NRC facility license.
(Brad.Reese@noaa.gov)

Dataset for Annual Exercise

At the request of INEEL Emergency Planning, we provided an artificial meteorological data set for the INEEL annual exercise on September 24, 2003. The artificial meteorological data is displayed on the exercise participants' computer screens exactly as real data is, allowing the exercise participants to see and react to a simulated release exactly as they would in an actual situation. Artificial data is used so that the release consequences will follow the scenario designed for the exercise. (Roger.Carter@noaa.gov)

Other Activities

Awards

Cash-In-Your-Account awards were given to three FRD personnel for their extraordinary efforts during the Joint Urban 2003 field experiment in Oklahoma City: Randy Johnson for rapidly designing and developing a new SF_6 sampler; Roger Carter for assisting in designing and developing a new SF_6 sampler; and Debbie Lacroix for operating and maintaining the Tracer Analysis Facility.

The award ceremony to present the Department of Commerce Gold Metal to Dr. Timothy Crawford (deceased) was scheduled to be held September 18. At the last minute is was postponed due to Hurricane Isabel and its forecast impact on Washington D.C. The ceremony will now be held December 5. Sharon Crawford will be receiving the Gold Metal on behalf of Tim, who was the FRD Director at the time of his death.

Travel

Jeff French to St. Croix for NOAA P-3 research flights into Hurricane Fabian, August 31 through September 7.

Jeff French to St. Croix for NOAA P-3 research flights into Hurricane Isabel, September 11 through September 15.

Kirk Clawson to Salt Lake City, UT for NOAA managers' DuPont safety training class, September 15 through September 17.

Rick Eckman and Tom Strong to North Carolina for ET Sphere data collection in Hurricane Isabel, September 16 through September 20.

Training

Kirk Clawson attended a two-day safety training course in Salt Lake City, UT that was taught by DuPont safety professionals. The course was held on September 16-17, and was mandated by senior NOAA management for supervisors of 10 or more employees. The course was jam-packed with techniques on how to improve work place safety from a manager's prospective. DuPont claims that all accidents are preventable. NOAA's safety vision is a bit more murky. However, the course has already resulted in improving safety procedures at FRD. Most notably, INEEL mesonet tower climbing without a spotter is now considered a safety violation. The servicing electronics technicians now form a twosome whenever a tower must be climbed for instrument servicing.

Visitors

Frank Sornatelli, AFTAC, Patrick AFB, Florida, visited on September 16 to discuss the merits of perfluorocarbon and sulfur hexafluroide tracers.